The Glasgow Naturalist (2009) Volume 25, Supplement. Machair Conservation: Successes and Challenges, 35-42

Phenology of Bombus distinguendus in the Outer Hebrides

Thomas G. Charman[1]*, Jane Sears[2], Andrew F. G. Bourke[3#] and Rhys E. Green[1,2]

[1] Department of Zoology, University of Cambridge, Downing Street, Cambridge CB2 3EJ, UK,
[2] Royal Society for the Protection of Birds, The Lodge, Sandy, Bedfordshire SG19 2DL, UK,
[3] Institute of Zoology, Zoological Society of London, Regent's Park, London NW1 4RY, UK

*Present address: Natural England, Ham Lane House, Ham Lane, Orton Waterville, Peterborough PE2 5UR, UK
#Present address: School of Biological Sciences, University of East Anglia, Norwich NR4 7TJ, UK
E-mail: Tom.Charman@naturalengland.org.uk; Jane.Sears@rspb.org.uk; A.Bourke@uea.ac.uk; reg29@hermes.cam.ac.uk

INTRODUCTION

In recent years British bumblebees have suffered massive declines in range and abundance (Alford 1975, Edwards & Williams 2004, Goulson 2003, Goulson *et al.* 2008, Williams 1985). One species has gone extinct and six others are listed as priorities for conservation action under the UK Biodiversity Action Plan (http://www.ukbap.org.uk/NewPriorityList.aspx). Of the remaining extant British species, *Bombus distinguendus*, the Great Yellow Bumblebee, has suffered the largest reduction in range (Gray 2003). *B. distinguendus* was formerly widely distributed throughout the British Isles, but is now restricted to a number of islands in the Inner and Outer Hebrides and Orkney and a handful of sites on the north coast of Scotland (Edwards 1997, 2002, http://data.nbn.org.uk/).

The patterns of distribution and decline shown by British bumblebees suggest that the loss, fragmentation and degradation of habitats are the major drivers of decline (Alford 1975, Carvell *et al.* 2006, Osborne & Corbet 1994, Williams 1982, 1985, 1986). Bumblebees have three main requirements during their colony cycle: (1) a suitable nest site, (2) a supply of pollen and nectar throughout the season and (3) a suitable place to hibernate (Sladen 1912, Free & Butler 1959). Recent landscape change has impacted on all of these requirements, however, the loss of forage is perhaps the biggest single cause of bumblebee decline (Carvell *et al.* 2006, Fussel & Corbet 1992, Goulson *et al.* 2008).

There is considerable scope to improve the availability of forage for bumblebees through direct planting and improved management of existing resources. This is already being achieved by agri-environment schemes for a small number of common and widespread species (Carvell *et al.* 2004, Pywell *et al.* 2006). However, there is insufficient understanding of the ecology of scarcer bumblebees to be able to develop effective conservation management.

The aim of this work was to fully describe the phenology of *B. distinguendus* in order to inform future management. Specifically it was aimed to establish when important forage plants are used and the timing of the colony cycle. *B. distinguendus* has previously received some study, but these studies have been relatively short and can only provide snapshots of its colony cycle (Edwards 1997, 1998, 1999, 2000, Hughes 1998).

METHODS

During summer 2005 T.G.C. collected a continuous time series of data on the flower use and colony cycle of *B. distinguendus*, on South Uist in the Outer Hebrides (23 May to 22 August 2005). The study area comprised the strip of machair stretching from Garrynamonie (Geàrraidh ma Mònadh, NF739160) in the south to Grogarry (Groigearraidh, NF755398) in the north (c. 25 km long and c. 2 km wide). High density patches of forage were visited at regular intervals throughout the season to record foraging bumblebees and flower abundance.

Patch selection

1 – 5 patches of each of ten focal flower species were selected (Table 1). These focal species are regularly used by *B. distinguendus* (Charman 2007) as well as being widespread and abundant in the Hebrides, i.e. they are plant species that provide a significant proportion of the forage requirements of *B. distinguendus*.

Where possible, each patch of a flower species was located in a different township in order to sample a different landscape context (e.g. different townships had different cropping patterns). Patches were selected to be the largest size and have the highest plant density within a township (to attract sufficient *B. distinguendus*) and to be accessible (e.g. not in hay crops). When two patches from the same township had to be used, these were at least 200 m apart. Some patches contained more than one forage species (Table

1). A linear 'bee walk' transect was established within each forage patch (see Table 1 for lengths).

Bee walk method

The field season was divided into nine periods of approximately 10-days: late-May, early-, mid-, and late-June and July and early- and mid-August (Table 1). Bee walks were conducted when patches were actively flowering by walking along the transect and systematically searching all forage within 2 m either side of it for foraging bumblebees. All bumblebees were identified to species and caste and the plant species they were foraging on was recorded. Each bee walk was repeated 2 – 8 times in a given period (Table 1). Usually these walks were conducted in succession on the same day. Given the high turnover of bees (*pers. obs.* from marking bees, also Heinrich 1979, Williams 1997) and that it usually took at least 30 mins to complete a walk, repeat counting of bees during the same foraging trip is likely to have been infrequent.

Quantifying abundance of floral resources

The number of flowers of bird's-foot trefoil, white clover, yellow rattle, kidney vetch, red clover and knapweed were counted in twenty 0.5 m^2 quadrats per patch (distributed regularly throughout the patch) once during each time period. Patches of tufted vetch tended to be smaller and have a more uniform flower density so flowers were counted in ten 0.5 m^2 quadrats per patch. Lesser burdock, spear thistle and ragwort are tall, widely dispersed plants that are not well suited to being monitored using quadrats and so instead they were monitored by counting the number of active flowers per plant on twenty randomly selected plants.

Flower use phenology

Phenologies were calculated separately for queen, worker and male *B. distinguendus* at each focal plant species. Each patch received more than one bee walk in each period when it was in bloom. For each patch , the average count of *B. distinguendus*, of each caste, seen per bee walk in each time period was calculated. These average bee counts were expressed as a proportion of the maximum average bee count at the patch, producing an index of bumblebee abundance ranging from 0 (no *B. distinguendus* of a given caste seen per bee walk at a patch) to 1 (maximum number of *B. distinguendus* of a given caste seen per bee walk at the patch). The bumblebee abundance indices in each time period were averaged across different patches of the same focal plant species (except for kidney vetch, which was only sampled with one patch). When doing this for a given caste, only the focal patches where at least one bee of that caste had been recorded were used. Finally these average *B. distinguendus* abundance indices were plotted against time period for each focal plant species.

Flowering phenology

The same method was used to calculate flowering phenologies as had been used for flower use phenologies, except that the first averaging step was not required because only one count of flowers was made per time period.

RESULTS

Caste composition

The first queen *B. distinguendus* of the year was seen on 21 May 2005. During May and June only queens were on the wing (Fig. 1). Workers emerged during July, and came to dominate by the end of July. They remained dominant through August but were joined by males, which became relatively more abundant as August progressed. A very small number of newly emerged queens were seen in August, but not all queens seen in August were newly emerged queens. Some were very worn and tattered and it is likely that thy had successfully founded a nest earlier in the season, but had subsequently lost dominance and had been forced to forage outside.

Flower use and flowering phenologies

3,438 visits to focal plant species by bumblebees of known species and caste were recorded. 407 of these were by *B. distinguendus* (111 queens, 266 workers and 30 males). Surprisingly, *B. distinguendus* was not recorded foraging at yellow rattle during the bee walks in 2005. However, the yellow rattle phenology has been included for completeness because it often is a regularly used forage source (Charman 2007). Fig. 2 shows the flower use phenologies of queen, worker and male *B. distinguendus* at each of the ten focal plant species alongside the flowering phenologies of each focal plant species. *B. distinguendus* use of the focal species closely matched the flowering pattern of the focal species for all ten flowers, except yellow rattle as described above. Bird's-foot trefoil, white clover, kidney vetch, yellow rattle, tufted vetch and red clover were all heavily used by queens, and, to a greater or lesser extent, by workers. Due to its early flowering period, bird's-foot trefoil was mostly visited by queens. Despite a similarly early start, white clover had a very protracted flowering period, which went through to July, when it was used by workers. The bulk of kidney vetch, yellow rattle, tufted vetch and red clover flowering occurred slightly later, in late June and July, during which time they received a mixture of visits from queens and workers. Lesser burdock, spear thistle, ragwort and knapweed provided forage for workers and males from late July through August and also received a handful of visits from queens, some of them newly emerged that year.

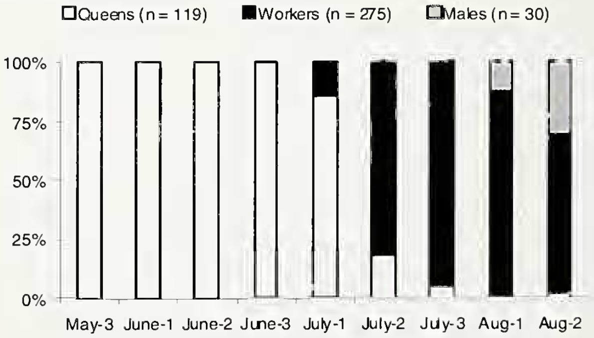
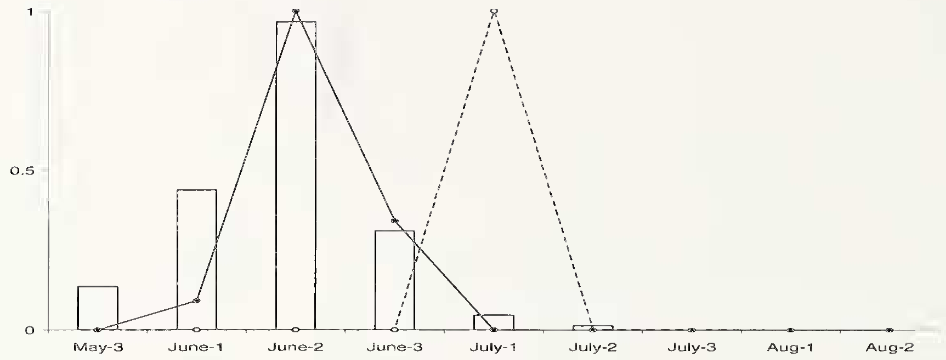


Fig. 1. The caste composition of *B. distinguendus* seen foraging on bee walks on South Uist during each time period in 2005.

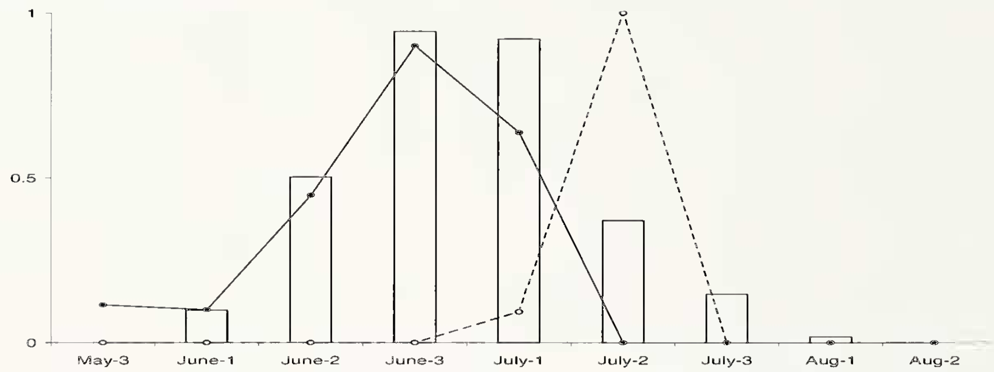
ID	Location	Description	Focal plant species										Length of transect or no. of plants	Number of visits								
														May	June			July			August	
			BT	WC	YR	KV	TV	RC	LB	ST	RG	KN		L	E	M	L	E	M	L	E	M
1	NF 7390 1583	Defunct fallow strip										1	200	-	-	-	-	-	-	-	2	2
2	NF 7389 1595	Fallow strip	1	1	1	1							280	-	8	8	4	4	3	3	2	-
3	NF 7365 1688	Dunes	1										320	-	8	8	4	2	-	-	-	-
4	NF 7367 1745	Fallow strip		1									300	-	-	16	8	4	3	3	2	-
5	NF 7336 1758	Fallow strip					1						85	-	-	-	2	2	2	2	-	-
6	NF 7342 1768	Fallow strip						1					300	-	-	-	-	4	2	2	2	2
7	NF 7308 1981	Fallow strip		1				1					300	-	-	12	8	4	3	2	2	2
8	NF 7309 1982	Fallow strip			1								275	-	-	-	1	4	3	-	-	-
9	NF 7331 1999	Fallow strip			1								200	-	-	-	1	4	3	-	-	-
10	NF 7315 2029	Dunes							1	1			310LB, 120ST	-	-	-	-	-	2	2	2	2
11	NF 7279 2627	Margins of track										1	80	-	-	-	-	-	-	-	2	2
12	NF 7284 2641	Fallow strip		1									280	-	-	4	8	4	3	2	2	-
13	NF 7279 2656	Dunes	1				1						400	-	8	8	4	4	2	2	2	-
14	NF 7286 2658	Fallow strip									1		400	-	-	-	-	-	1	2	2	-
15	NF 7283 2658	Fenced strip margin										1	180	-	-	-	-	-	-	-	2	2
16	NF 7549 3639	Fallow strip						1					300	-	-	-	-	1	3	2	2	2
17	NF 7520 3644	Dunes					1						120	-	-	-	2	2	2	2	2	-
18	NF 7515 3680	Dunes	1	1									375	7	8	8	4	4	3	-	-	-
19	NF 7539 3881	Dunes									1		330	-	-	-	-	-	1	2	2	2
20	NF 7542 3899	Dunes	1										300	8	8	8	4	4	-	-	-	-
21	NF 7545 3899	Margin of fallow strip							1	1			368LB, 82ST	-	-	-	-	-	2	2	2	2
			5	5	3	1	3	3	2	2	2	3										

Table 1. Characteristics of focal patches used on South Uist in 2005, including the plant species that they cover and the number of bee walks they received in each time period. BT = bird's-foot trefoil, WC = white clover, YR = yellow rattle, KV = kidney vetch, TV = tufted vetch, RC = red clover, LB = lesser burdock, ST = spear thistle, RG = ragwort, KN = knapweed. The length of transects used to survey each patch are also given (in m) except for lesser burdock and spear thistle (where much of the transects were simply gaps between individual plants) and instead sampling effort for these patches is given in terms of the number of plants surveyed.

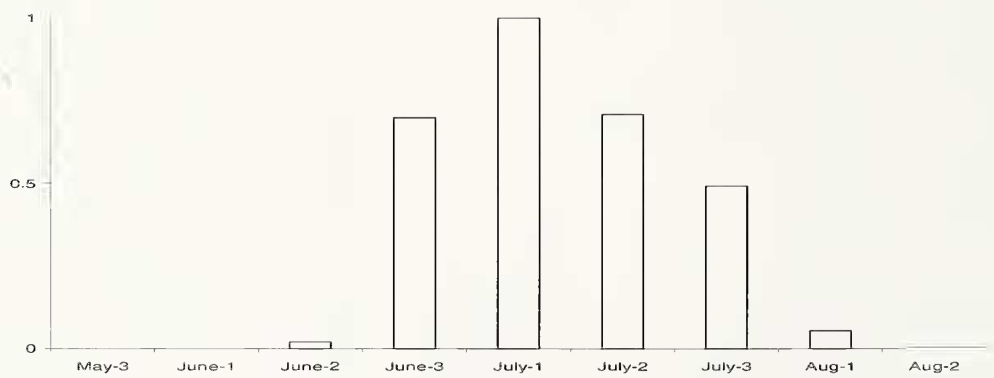
(a) Bird's-foot trefoil



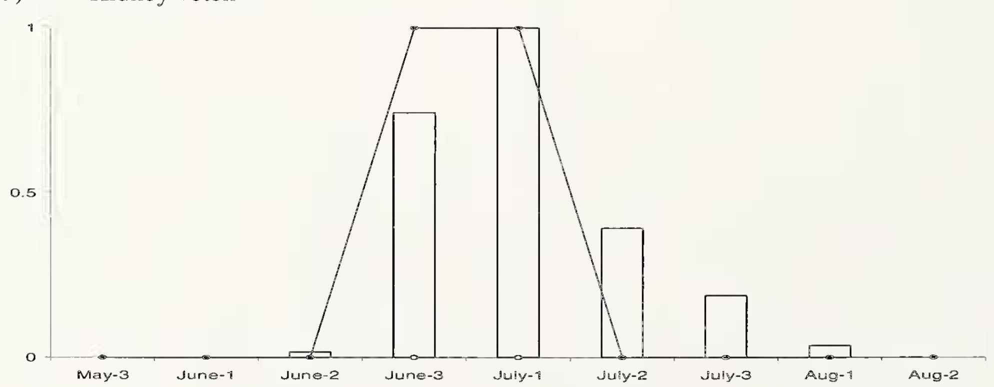
(b) White clover



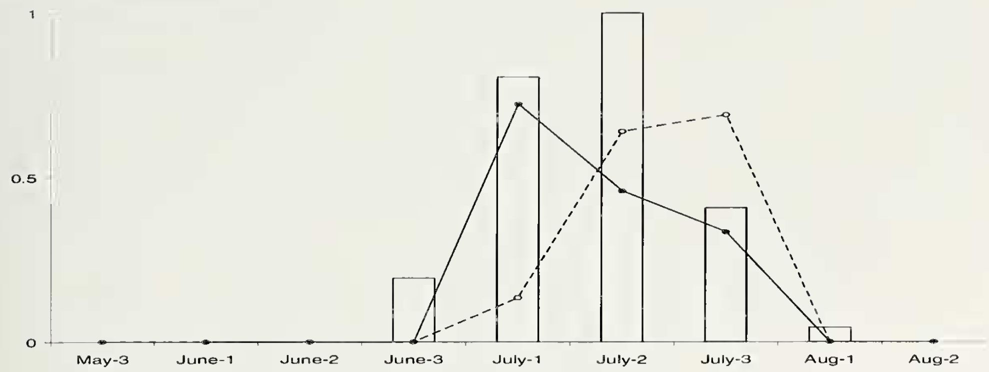
(c) Yellow rattle



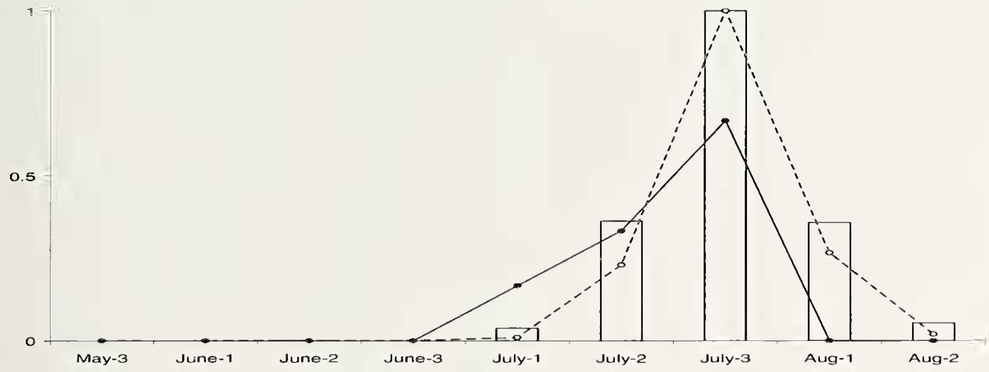
(d) Kidney vetch



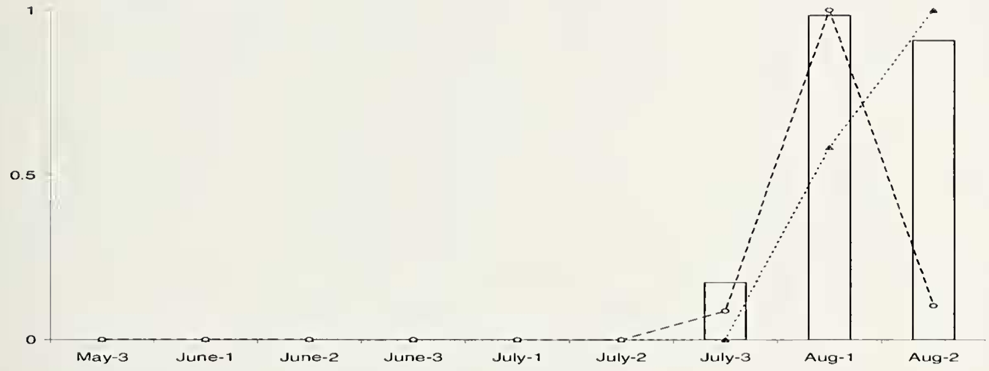
(e) Tufted vetch



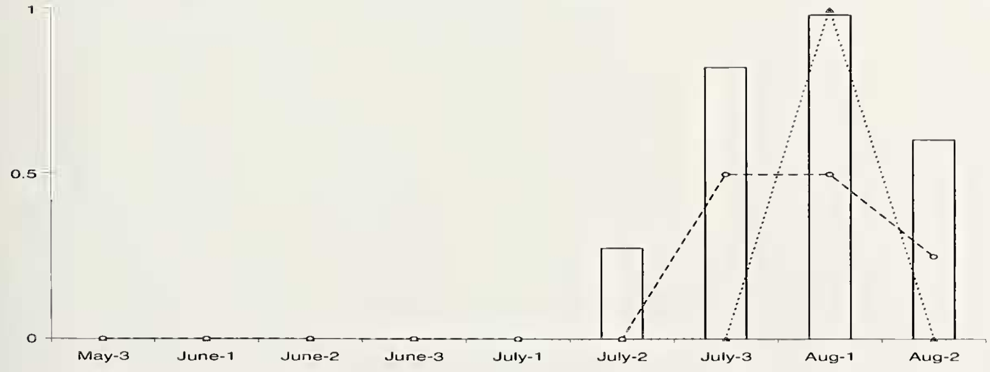
(f) Red clover



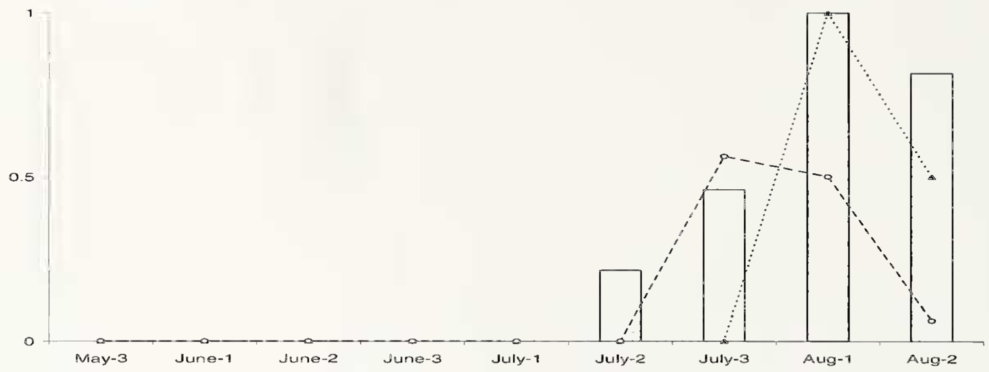
(g) Lesser burdock



(h) Spear thistle



(i) Ragwort



(j) Knapweed

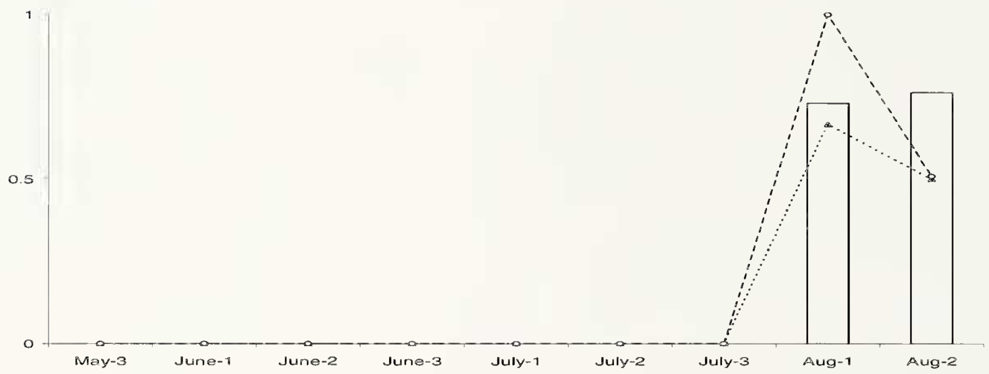


Fig. 2. Abundance of *B. distinguendus* and abundance of flowers of the focal plant species in each time period during summer 2005, for each focal plant species (a – j). The abundance of flowers is illustrated with bars and the abundance of *B. distinguendus* is illustrated with points joined with lines. Queens are shown with solid circles joined by solid lines, workers by hollow circles joined by dashed lines and males by solid triangles joined with dotted lines. June-1 = early-June, June-2 = mid-June, June-3 = late-June, *etc.*

DISCUSSION

This study used regularly repeated, standardised counts of bumblebees and flowers at high-density patches of forage to quantify the phenology of the flower use of *B. distinguendus* and its colony cycle in the Outer Hebrides. This has showed that *B. distinguendus* is a "late"-emerging and nesting bumblebee (Edwards & Williams 2004) with a "medium" length (Benton 2006) colony cycle. No single plant species provided resources throughout this period, which implies that *B. distinguendus* therefore requires a succession of suitable forage species in order to successfully complete its cycle and reproduce. The flowering periods of ten of these regularly visited plant species have been described.

Synthesising data gathered in this study with that in previous work (Edwards 1997, 1998, 1999, 2000, Hughes 1998), an "average" *B. distinguendus* colony cycle in the Outer Hebrides can be described as follows: The first queens to emerge usually appear during mid to late May. Nest-searching follows in mid June through to early July with a peak of activity in late June. Workers start to emerge from the beginning of July onwards and foragers gradually switch from a community dominated by queens, to, by the end of July, one dominated by workers. Males are seen foraging from the start of August. The timing of new queen emergence is least well known, as new queens are rarely observed. Like males, they can be seen from the beginning of August, although it appears that their main emergence period is a week or two later (Benton 2006). It should also be noted that there is considerable variation between seasons in the timing of the *B. distinguendus* colony cycle. For example, in 2004 the switch from foraging *B. distinguendus* largely comprising queens to foraging *B. distinguendus* mostly being workers occurred about 10 days later than in 2005 (Charman 2007).

Edwards and Williams (2004) divide bumblebee species into two main groups, "early" and "late", whose colony cycles, they propose, are timed to take advantage of specific periods of floral abundance. They suggest early species are associated with garden/woodland edge habitats, which provide forage from early in the season, while in contrast, "late" species are open-ground species associated with flower-rich, but late-flowering grasslands. Assigning a bumblebee phenology to one of these groups is complicated by a north – south gradient in the timing of colony cycles. Within the same species, bumblebees in more northern regions emerge considerably later than their southern counterparts (e.g. Benton 2000, MacDonald & Nisbet 2005). However, a comparison with phenologies within the Highland region (MacDonald & Nisbet 2005) reveals that *B. distinguendus* is indeed a "late" species. For example, in Highland, *B. terrestris* queens emerge in late March, and are on the wing until May.

Many late-emerging species have suffered large declines, while most early-emerging species remain widespread and abundant (Edwards & Williams 2004). This study has shown that *B. distinguendus* is a relatively late emerging and nesting bumblebee, and having suffered a large-scale decline, also fits this pattern. Colony cycle phenology could be associated with magnitude of decline by a number of different mechanisms. For instance, the amount of late forage available in Britain may have declined more than the amount of early forage (Edwards & Williams 2004) – in the 20th century there has been a large-scale shift from late-cut herb-rich hay meadows to early-cut or intensively grazed monocultures of grass, and between 1932 and 1984 over 90% of unimproved lowland grassland has been lost (Fuller 1987). In addition, if nest sites are limiting, then by the time "late" species emerge most nest sites may have already been occupied by "early" bumblebee species.

The approximate three month colony cycle (late May to late August) places *B. distinguendus* in the "medium" length group (Benton 2006, Goodwin 1995). No single plant species provided resources throughout this three month period and *B. distinguendus* therefore requires a succession of suitable forage in order to successfully complete its cycle and reproduce. Furthermore, these different plant species are present in different vegetation communities, at different stages of succession. For example, knapweed is found in areas that have not been disturbed except by light winter grazing. In order to maintain populations of *B. distinguendus* it is therefore important to retain a variety of different land uses on the machair.

ACKNOWLEDGEMENTS

This work formed part of T.G.C.'s Ph.D. thesis, which was generously funded by the Natural Environment Research Council and the RSPB. We would like to thank the Crofters of the Uist machair for allowing free access to their land and to RSPB field staff for assistance throughout the project. Elisabeth Charman provided useful criticism of the manuscript.

REFERENCES

Alford, D. V. (1975) *Bumblebees.* Davis-Poynter, London.

Benton, T. (2000) *The bumblebees of Essex..* Lopinga Books, Ipswich.

Benton, T. (2006) *Bumblebees: The Natural History and Identification of the Species found in Britain.* Collins, London.

Carvell, C., Meek, W. R., Pywell, R. F. & Nowakowski, M. (2004) The response of foraging bumblebees to successional change in newly created arable field margins. *Biological Conservation* 118, 327-339.

Carvell, C., Roy, D.B., Smart, S.M., Pywell, R.F., Preston, C.D. & Goulson, D. (2006) Declines in forage availability for bumblebees at a national scale. *Biological Conservation* 132, 481-489.

Charman, T.G. (2007) *Ecology and Conservation Genetics of Bombus distinguendus, the Great Yellow Bumblebee*. Ph.D. Thesis, University of Cambridge.

Edwards, M. (1997) *Survey of Bombus distinguendus* Morawitz *(Hymenoptera: Apidae) on the Outer Hebrides, August 1997.* English Nature, Peterborough.

Edwards, M. (1998) *UK BAP Bumblebee Working Group Report 1998.* English Nature, Peterborough.

Edwards, M. (1999) *UK BAP Bumblebee Working Group Report 1999.* English Nature, Peterborough.

Edwards, M. (2000) *UK BAP Bumblebee Working Group Bombus distinguendus 2000 Projects.* English Nature, Peterborough.

Edwards, M. (2002) *UK BAP Bumblebee Working Group Report 2002.* English Nature, Peterborough.

Edwards, M. & Williams, P. H. (2004) Where have all the bumblbeees gone, and could they ever return? *British Wildlife* 15, 305-312.

Free, J. B. & Butler, C. G. (1959) *Bumblebees.* Collins, London.

Fuller, R. M. (1987) The changing extent and conservation interest of lowland grasslands in England and Wales: a review of grassland surveys 1930-84. *Biological Conservation* 40, 281-300.

Fussel, M. & Corbet, S. A. (1992) Flower usage by bumblebees: a basis for plant management. *Journal of Applied Ecology* 29, 451-465.

Goodwin, S. G. (1995) Seasonal phenology and abundance of early-, mid- and long-season bumble bees in southern England, 1985-1989. *Journal of Apicultural Research* 34, 79-87.

Goulson, D. (2003) *Bumblebees: Behaviour and Ecology.* Oxford University Press, Oxford.

Goulson, D., Lye, G.C. & Darvill, B. (2008) Decline and Conservation of Bumble Bees. *Annual Review of Entomology* 53, 191-208.

Gray, S. (2003) *Causes of Decline in UK Bumble Bees.* Part II project, Department of Zoology, University of Cambridge.

Heinrich, B. (1979) *Bumblebee Economics.* Harvard University Press, Cambridge, Massachusetts and London.

Hughes, L. (1998) *The Great Yellow Bumblebee, Bombus distinguendus* (Morawitz)*: Aspects of Habitat Use, Phenology and Conservation on the Machair of the Outer Hebrides, UK.* MSc. Thesis, University of London.

MacDonald, M. A. & Nisbet, G. (2005) *Highland Bumblebees: Distribution, Ecology and Conservation.* Big Sky, Findhorn.

Osborne, J. L. & Corbet, S. A. (1994) Managing habitats for pollinators in farmland. *Aspects of Applied Biology* 40, 207-215.

Pywell, R. F., Warman, E. A., Hulmes, L., Hulmes, S., Nuttall, P., Sparks, T. H., Critchley, C. N. R. & Sherwood, A. (2006) Effectiveness of new agri-environment schemes in providing foraging resources for bumblebees in intensively farmed landscapes. *Biological Conservation* 129, 192-206.

Sladen, F. W. L. (1912) *The Humble-Bee.* Macmillan, London.

Williams, C. S., (1997) *Foraging Ecology of nectar-collecting bumblebees and honeybees.* Ph.D. Thesis, University of Cambridge.

Williams, P. H. (1982) The distribution and decline of British bumble bees (*Bombus* Latr.). *Journal of Apicultural Research* 21, 236-245.

Williams, P. H. (1985) *On the distribution of bumble bees (Hymenoptera, Apidae) with particular regard to patterns within the British Isles.* Ph.D. Thesis, University of Cambridge.

Williams, P. H. (1986) Environmental change and the distribution of British bumble bees (*Bombus* Latr.). *Bee World* 67, 50-61.